ENERGY MATTERS

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An Office of Industrial Technologies
Bimonthly Publication Focusing on
Energy Efficiency Opportunities for Today

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Issue Focus: Motor, Steam, Compressed Air Systems Management

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Your Proposal Could Lead to Substantial Cost Savings for Your Plant—Submit it Now!

Oak Ridge National Laboratory (ORNL), on behalf of DOE's Office of Industrial Technologies (OIT), is interested in obtaining proposals from industrial manufacturing plant sites for plant-wide assessments that will lead to substantial improvements in industrial energy efficiency, waste reduction, productivity, and global competitiveness.

The overall goal of such plant assessments is to develop a comprehensive strategy that will significantly increase plant energy efficiency and reduce environmental emissions. In this regard, ORNL strongly encourages industrial sites to work closely with their resource and equipment suppliers, engineering firms, and other third party entities. Funding of up to $75,000 is available for each project selected with a required industrial cost share of at least 50%.

We are interested in industrial sites that take a comprehensive, plant-wide systems approach to increasing energy efficiency and reducing environmental emissions. Specifically, proposals are sought where teams will be considering the adoption of best available and emerging technology using state-of-the-art tools, information, process engineering techniques, and best practices for operating and planned plant support and process systems. Priority will be given to proposals for plant assessments from industrial sites that fall within the OIT Industries of the Future (IOF) initiative, including: Forest Products, Chemicals, Petroleum, Steel, Aluminum, Metalcasting, Glass, Mining, and Agriculture.

It is expected that the plant assessments will address a variety of generic and industry-specific technology areas, and a variety of plant/process optimization methods. Proposers should also consider demand-side energy management best practices and technology implementation in plant steam delivery and process heating systems, electric-motor systems (including motors, drives, pumps, fans, blowers), compressed air systems, and heat exchange optimization (e.g., pinch technology), as well as, supply-side options using cogeneration and combined heat and power system technologies.

The results, successes, and experiences from these assessments will be published to encourage other U.S. industrial companies to adopt and implement a comprehensive, plant-wide systems approach to increasing energy efficiency and reducing environmental emissions. In this way, it is desired to increase the market penetration of energy-efficient systems across U.S. industry and to increase industrial energy efficiency, waste reduction, productivity, and global competitiveness. Participating plants will be made aware of, and provided technical assistance to accessing, all OIT emerging technology and best practices, and tools and information resources that could assist the plants in implementing the most cost-effective state-of-the-art technology.

Parties interested in receiving the RFP should contact:

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Look to upcoming issues of *Energy Matters* to help you:

- "Sell" energy-efficient projects to management
- Identify the benefits of contracting services
- Assess energy-saving new technologies
- Answer reliability based maintenance issues
- Understand adjustable speed drive technologies

Take a few minutes to read through the enclosed copy of *Energy Matters*. The May issue focuses on motor, steam and compressed air systems management and includes articles on planned upgrades, improving boiler efficiency, and field measurements. You'll also find a supplement devoted to ways to help you improve industrial steam system efficiency.

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Boiler System Efficiency Improves with Effective Water Treatment

By Michael Frasca, Boiler Technology Marketing, Nalco Chemical Company, Naperville, IL

Minimizing energy costs while maintaining high boiler reliability is one of the main objectives of every utility system operator. Optimization of boiler combustion controls, minimizing stack losses, and installation of heat recovery equipment are obvious big-ticket items. Water treatment, although typically a smaller payback item, is also important.

There are many opportunities, as discussed in this article, to improve boiler system efficiency through the use of chemical treatment.

Reduce Boiler Scale

Boiler scale creates a problem in boiler operation because scale typically possesses a low thermal conductivity (relative to a clean metal surface). The presence of scale is equivalent to having a thin film of insulation across the path of heat transfer from the furnace gases to the boiler water. This heat-insulating material retards heat transfer and causes a loss in boiler efficiency. Stack gas temperatures may increase as the boiler absorbs less heat from the furnace gases.

Heat transfer may be reduced as much as 10%-12% by the presence of scale. A scale approximately 1/8-inch thick may cause an overall loss in boiler efficiency of about 2%-3% in fire tube boilers as well as in the convective sections of water-tube boilers. Even more important than the heat loss is that scale can cause overheating of the boiler tube metal and can result in subsequent tube failures. Costly repairs and boiler outages are the result of such a condition (Figure 1).

Scale formation in boilers can be controlled by chemical treatment in combination with the proper operation and maintenance of all make-up and feedwater pretreatment systems. Phosphates, chelates, and polymers are among the treatments in common use today to condition and/or maintain solubility of scale-forming solids within the boiler.

Optimize Boiler Blowdown Rates

Proper control of blowdown is a critical part of boiler operation. Insufficient blowdown may lead to deposits or carryover, while excessive blowdown will waste water, heat, and chemicals. The American Society of Mechanical Engineers (ASME) has developed a consensus on operating practices for boiler feedwater and blowdown that is related to operating pressure. These suggestions apply for both steam purity and deposition control.

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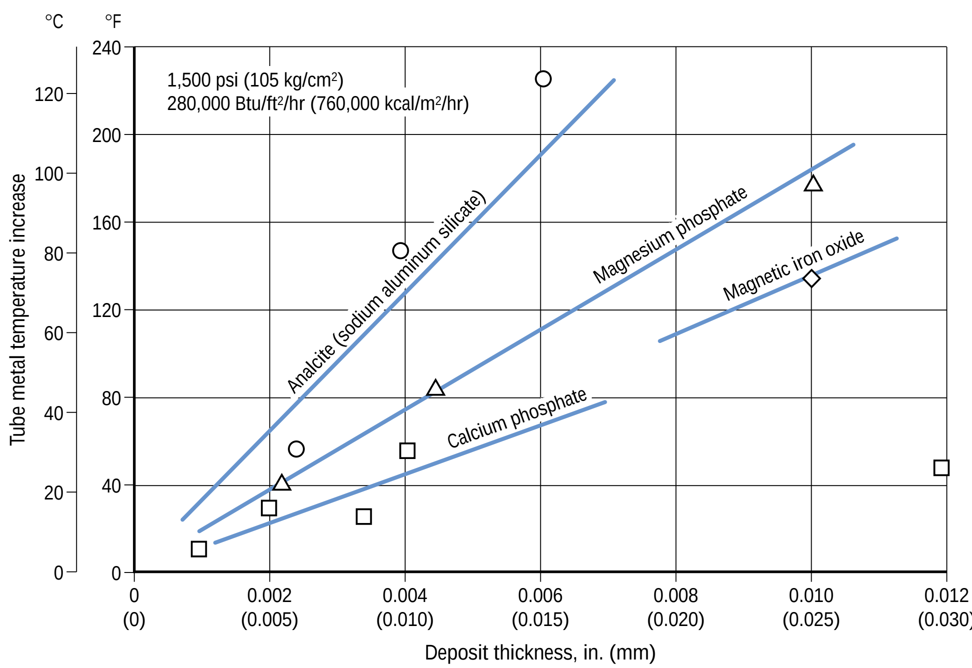

Figure 1. Effect of boiler scale on tube metal temperature.

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The ASME limits are a good starting point in establishing blowdown needs. Operating experience with a particular boiler then determines whether or not it is practical to deviate from these limits. A steam purity study can help set new boiler limits which will minimize solids carry-over, while also maintaining minimum blowdown rates.

Once specific limits for boiler water solids have been set, a practical way is needed to control solids level on a day-to-day basis. Conductivity, TDS, silica, chlorides, and/or alkalinity is often used to control the rate of blowdown. These tests, however, are often subject to interference and may be difficult to measure accurately in high-purity feedwater systems.

An inert fluorescent tracer can be used to accurately measure boiler cycles and chemical feed. Typically, the increased accuracy and confidence from using an inert fluorescent tracer will allow boiler cycles to be increased, resulting in significant savings.

Reduce Iron and Copper Pick-up in the Feedwater

Oxygen scavengers developed within the last 20 years may be more than their name implies. Some provide both chemical oxygen scavenging and passivation of the pre-boiler or feedwater system. (Passivation is the formation of a very thin, dense, protective iron oxide film, commonly magnetite, on the metal surface. Passivation typically increases the corrosion resistance of a metal surface.) These oxygen scavengers are used to prevent corrosion in the feedwater system. Reduced corrosion minimizes the transport of corrosion products to the boiler and also to the superheaters if feedwater is used for attemperation.

Testing under laboratory conditions has determined that carbohydrazide is the best passivating agent at all temperatures, followed by erythorbic acid and then hydrazine. Reduction of feedwater iron and copper concentrations by carbohydrazide has been confirmed in actual boiler systems.

Reduce Feedwater to the Boiler

The maximum achievable cycles in a boiler is often limited by TDS or conductivity. In boiler systems using sulfite as an oxygen scavenger, switching to a non-sulfite scavenger can reduce feedwater TDS and improve boiler system efficiency. Sulfite is commonly fed to maintain a residual in the boiler water (Table 1). In contrast, the non-sulfite scavenger dosage is based on a small feedwater residual, typically about 1 ppm. In addition, some of the alternative scavengers do not themselves contribute to boiler water TDS or conductivity. For a typical boiler operating at 200 psig, 550,000 lbs/day steaming rate, and 5.5 cycles, the savings from switching to a non-sulfite scavenger would total $23,000 in fuel costs annually.

Table 1. Recommended Boiler Water Sulfite Residual

Boiler Pressure, Psig [Mpa]	Residual Range, ppm
Below 300 [<2.07]	30-60
301-600 [2.08-4.14]	20-40
600-900 [4.14-6.21]	15-30
Above 900 [>6.21]	Not recommended[1]

[1] Original recommendations extended above 900 psi, however, thermal breakdown of sulfite typically limits modern day use to systems operating below 900 psi.

Steam/Condensate System

One economically attractive method of maximizing energy efficiency and boiler reliability is by increasing the amount of condensate return. Returned condensate, being condensed steam, is extremely pure and has a high heat content. Increased condensate return can improve boiler system economics through water and energy conservation.

As more condensate is returned, less make-up is required, saving on water and make-up water treatment costs. The high purity allows for greater boiler cycles of concentration, thus reducing water and energy losses to blowdown. The high heat content (typically in excess of 180°F) can provide substantial energy savings. Additional savings will also be noted in reduced water treatment chemicals, water and sewer costs. For a typical boiler operating at 600 psig, 2,400,000 lbs/day steaming rate, and 13 cycles, the savings from increasing the condensate return 10% would total $132,000 in fuel costs annually.

Corrosion in condensate systems can limit the quality or quantity of returned condensate because of iron and copper corrosion products, which can deposit on boiler heat transfer surfaces. This reduces heat transfer efficiency and could cause tube failure. Condensate corrosion control is required to protect process equipment, lines, tanks, as well as to maintain the condensate as a quality feedwater source. Corrosion of the condensate system can result in increased maintenance and equipment costs, energy loss through steam leaks and loss of process heat transfer efficiency.

To prevent condensate corrosion, volatile neutralizing amines, such as cyclohexylamine, morpholine, and diethylaminoethanol, are typically used to neutralize carbonic acid and raise the condensate pH. These programs are most effective when fed to maintain a minimum pH of 8.5, ideally 8.8 to 9.2. A blend of several amines will assure that corrosion protection is distributed throughout the entire steam/condensate system. Filming amines and a new, patented chemistry are alternative condensate treatments.

Summary

There are many opportunities to improve boiler system efficiency through the use of chemical treatments. Water treatment is an important aspect of boiler operation that can improve efficiency and availability, or result in damage if neglected.

For questions or comments, call Mike Frasca at (630) 305-1625 or send e-mail to mfrasca@nalco.com.

DOE Industrial Assessment Center Helps Georgia Quarry Reduce Maintenance Requirements and Energy Costs

Each year, the Energy and Environmental Management Center (EEMC) at the Georgia Institute of Technology (Georgia Tech) conducts 25 to 40 energy, waste and productivity assessments, partly supported by its role as a DOE Industrial Assessment Center (IAC).

In February 1997, the EEMC, a Motor Challenge Allied Partner, completed an assessment of the Blue Circle Aggregates quarry in Lithonia, Georgia, outside Atlanta. The Lithonia quarry, one of 10 quarries operated by Blue Circle Aggregates in Georgia, produces 1.8 million tons of aggregate and manufactured sand for construction and road building each year. Excavating, moving, screening, and processing these materials consume approximately 4 million kWh annually and create a demand of about 500 kW.

Based on their assessment, the EEMC staff recommended three motor system upgrades for the Lithonia quarry. Implementing the motor system upgrades has reduced yearly energy consumption at the quarry by nearly 250,000 kWh and demand by 81 kW, resulting in cost savings of over $21,000 per year. These energy and demand savings are 6.2% and 16% of their respective annual figures.

Motor System Upgrades

The three motor system upgrades were initiated in January 1997 after the Lithonia Quarry Manager approached the EEMC requesting an IAC assessment. Soon afterward, the EEMC presented the results and their recommendations to the Quarry Manager and Blue Circle Aggregates' Director of Environmental Services, who reviewed the report and set priorities for the Lithonia quarry. They were convinced that the combined benefits of reduced maintenance and improved energy and environmental performance were greater than the cost of the upgrades.

Upgrade 1: Reduce Horsepower of Water Pumps

The greatest energy savings resulted from reducing the capacity of three large water pumps. The quarry has two water sources—a quarry pit and a stream some distance away. The EEMC found that the quarry pit could provide all the necessary water for quarry operations. Therefore, reducing the use of the main pump from the stream and two additional circulation pumps reduced power requirements by 140 horsepower (Table 1).

Upgrade 2: Lower Hydro-Cyclone Elevation

The second system upgrade reduced pumping costs by physically lowering part of the 10-element hydro-cyclone unit at the quarry by 80 feet. This upgrade cost approximately $5,100 and resulted in annual monetary savings of $3,400— a simple payback of 1.5 years (Table 1).

Water pump at Blue Circle Aggregates' Lithonia quarry.

Upgrade 3: Replace Four Motors with Energy-Efficient Motors

The third recommended upgrade includes replacement of four standard efficiency motors with high-efficiency models upon burnout. The EEMC completed the economic evaluations for this upgrade using MotorMaster+. (Table 1)

The EEMC further recommended that Blue Circle Aggregates change their motor policy to specify that *all* motors operating more than 3,000 hours per year be replaced with high-efficiency motors upon burnout. Doing so would have an average payback of about 2.4 years.

Blue Circle Aggregates' On-going Upgrades

After completing the Lithonia quarry assessment, the EEMC completed assessments at two other Blue Circle Aggregates facilities. Since then, Blue Circle Aggregates' own staff has completed five more assessments of their own. "They did need some additional assistance after we submitted the report for the Lithonia quarry," says John Adams, Georgia Tech EEMC Director, "but Blue Circle Aggregates' corporate Environmental Manager has kept the project alive and full of vitality."

Blue Circle Aggregates' current plan is to implement at each plant upgrades similar to these three quarry upgrades.

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Table 1: Motor System Upgrade Savings

Motor	HP	kW Savings	kWh Savings	$ Savings
Upgrade 1: Reduce Horsepower of Water Pumps				
Water Pump #1	50	20.1	60,400	$ 5,260
Water Pump #2	75	28.0	89,900	7,320
Water Pump #3	15	9.8	29,500	2,570
Upgrade 1 Totals	140	57.8	179,800	$15,150
Upgrade 2: Lower Hydro-Cyclone Elevation				
Upgrade 2 Totals	N/A	13.1	39,300	$ 3,400
Upgrade 3: Replace Four Motors with Energy-Efficient Motors[1]				
Crusher	200	2.4	7,218	$ 629
Pump #2	150	2.4	7,296	636
Pump #3	200	2.4	7,218	629
Pump #6	140	2.6	7,718	673
Upgrade 3 Totals	690	9.8	29,450	$ 2,567
Grand Totals	837	80.8	248,640	$21,117

[1] Savings based on 3,000 hours of operation per year and replacement upon motor failure.

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Georgia Tech's Energy and Environmental Management Center

Because of its experience with the type of operations targeted by DOE's Office of Industrial Technologies, the EEMC became a DOE Industrial Assessment Center (IAC). As an IAC for almost 20 years, the EEMC has provided over 650 in-depth IAC assessments at no-charge to eligible manufacturing plant sites.

John Adams feels it was an easy progression from being a Department of Energy IAC to becoming a Motor Challenge Allied Partner. As a Motor Challenge Allied Partner, the EEMC conducts seminars and workshops and performs in-plant energy audits. "We routinely demonstrate the MotorMaster+ software then leave the customer with a copy for their own use," says Adams. "We like to teach by example," he adds.

Contact John Adams at (404) 894-4138.

DOE's Industrial Assessment Centers

As one of 29 Industrial Assessment Centers based at universities around the country, the EEMC provides energy, waste, and productivity assessments at no charge to small and medium-sized manufacturers, many of which are Motor Challenge Partners. These assessments help manufacturers maximize energy efficiency, reduce waste, and improve productivity. Average savings of greater than 10% of annual utility costs typically result from implementing the assessment recommendations.

To be eligible for an IAC assessment, a manufacturing plant must meet the following criteria:

- *Primary business within Standard Industrial Classification (SIC) codes 20-39;*
- *Located within 150 miles of an IAC host campus;*
- *Gross annual sales less than $75 million;*
- *Fewer than 500 employees at plant site;*
- *Annual energy bills greater than $75,000 and less than $1.75 million; and*
- *Employ no professional, in-house staff able to perform the assessment.*

For information about an energy audit for your plant, please call (800) 862-2086.

Data Logging a Plant Compressed Air System

By Robert E. Wilson, ConservAIR Technologies Co. LLP

While pressure readings at the point of generation provide important information, they do not portray a complete and accurate picture of the system's overall performance. A system can have very stable pressure in the compressor room while experiencing major pressure fluctuations in the production area. Fluctuations can be localized or affect the entire distribution pressure. If fluctuations affect production, the typical response is to increase compressed air supply, which increases operating costs.

A compressed air system cannot be evaluated or controlled from the supply side; performance must be measured on the production floor. Evaluating air system efficiency requires a comparative review of both supply-side and demand-side pressure profiles.

Data logging is an excellent way to define performance and identify problems in an industrial compressed air system. However, to be useful, data acquired must by correctly interpreted.

Define Specific Objectives

Before data logging your system, define your objectives. Keep the objectives specific to key issues. Focus on the information desired not the actual data. Put away preconceived notions about current performance and solutions.

Key questions as they relate to one point of pressure data are:

- Is pressure too high or too low?
- What is too low?
- Is pressure consistent?
- How consistent should it or can it be?
- When pressure increases, why does it increase?
- Did pressure increase because another compressor loaded up or because an event demand went away?
- If pressure decreased, what was the cause?
- Is the system driven by the compressors, are the compressors responding to demands, or both?

To make data meaningful, you must ask the right questions, then compare and evaluate with other pressure point data in a total system analysis.

Today's data logging equipment simplifies the review process and offers a valuable tool for those who have some knowledge and experience with compressed air systems. Used properly, a data logger defines your system's pressure profiles and shows how the system is operating.

Develop Test Procedures

After determining objectives, develop a test procedure. Select, identify, and list monitoring points and parameters. Also, specify sampling rates and the duration of the data logging.

Pressure is the easiest and most definitive measure of system performance. Other variables such as barometric pressure, temperature, fixed volume, moisture content, demand load profile, and leaks remain relatively constant for a specific system and duration of data gathering. Therefore, the conclusions derived from a *comparative* evaluation are valid.

Amperage readings are relatively easy to log. Flow and kW can then be estimated based upon the compressor manufacturer's published data. Again, if the same assumptions are used before and after, the conclusions derived from the comparative evaluation will be valid.

At a minimum, pressure must be logged at the generation point in the compressor room(s), at representative points in the piping distribution system, and at critical-use points.

A typical data logger allows four or more simultaneous measurements. Multiple loggers can be used at different locations within the air system. The key to proper interpretation is to sample data simultaneously at representative locations in the compressor room(s), piping header(s), and use point(s). The sampling must accurately represent your operation.

Instantaneous and Trending Operating Profiles

A pressure drop shows a change in pressure as it relates to a point in time. A trending profile shows the pressure change across the system.

Instantaneous profiling helps determine dynamic peak, average, and valley demands of the system and the amplitude of pressure fluctuations. Trending should be conducted over a time period representative of the production schedule being evaluated—typically over 24-hour periods and off-peak times. A comparison of samplings in various locations is used to determine pressure gradient across the system.

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Performance Optimization Tips

Field Measurements—Practicalities and Pitfalls in a Parabolic Context

By Don Casada, Motor Challenge Program, Oak Ridge National Laboratory

Note: This article, focusing on understanding the changing picture of system operations, is the third of a series dealing with potential pitfalls in field measurements of motor systems. The first appeared in the November 1998 issue of Turning Point.

Centrifugal loads, such as pumps, fans, and compressors are responsible for a large fraction of industrial electrical energy consumption (1). The opportunities for reducing energy consumption in these systems are often significant. Any effort to do so inherently requires three fundamental pieces of information:

- The big picture—clearly identified functional requirements of the system.
- An understanding of how the picture changes over time.
- Actual measurements in the field.

The first two elements, which should always precede and provide the focus for actual measurements, were covered in previous articles that appeared in the November 1998 *Turning Point* and the March 1999 issue of *Energy Matters.* This issue will begin covering the third, subsidiary element.

As an employee at a national laboratory, I occasionally get involved in experimental testing and analysis. Since the goal of the testing is to produce useful and reliable test results, a good deal of attention is paid to instrumentation issues such as accuracy, range, calibration, proper physical configuration, etc., as well as test protocols. If an important parameter cannot be monitored with already installed instruments, the facility is modified to add the needed equipment. Details are important, since experimental accuracy is of premium value. Fortunately, professional societies, such as the American Society of Mechanical Engineers (ASME), the Hydraulics Institute, and the Institute of Electrical and Electronics Engineers (IEEE) have written excellent testing standards (2, 3, 4, 5) that address instrumentation and procedural issues.

In many industrial systems, little thought is given to process monitoring issues *unless* the parameter to be monitored is critical to product quality or quantity. For example, if a pumping system is used to remove heat from another process, little attention may be paid to instrumentation issues in the pumping system itself either before or after the system is put in service. This is natural, since the system exists to support the process, not experimental testing. As a result, the process instrumentation that does exist is frequently in undesirable locations (such as a flow meter located two pipe diameters downstream of a control valve), and it is seldom, if ever, calibrated. So while the basic principles on which the test standards are founded are certainly valid in the real world, the supporting instrumentation frequently is not.

If we are to even estimate potential energy reduction opportunities in centrifugal systems, parameters such as flow rate, pressures, and electrical power must be known. Facility managers and operators are uniformly unenthusiastic about cutting or drilling holes in pipes to install meters if the system has been meeting the process goals. In the absence of reliable permanently installed instruments, how does one go about measuring or estimating critical performance parameters in these systems?

Pumping Systems Field Monitoring

The balance of this issue and subsequent issues of this column will discuss alternative methods of either measuring or estimating important energy-related parameters in pumping systems[1] when less than ideal instrumentation is encountered.

From the following expression of overall pump and motor efficiency, which is simply the ratio of the fluid power to the electric input power, the primary parameters of importance in pumping systems are self-evident:

$$\eta_t = \frac{H \cdot Q \cdot \gamma}{P_e}$$

where η_t is overall efficiency, H is the head, Q is the volumetric flow rate, γ is the fluid specific weight, and Pe is electrical input power.

From a practical standpoint, fluid temperature and rotational speed are parameters that are also important to monitor. Starting with head in this issue, each of these elements will be discussed in this column. The focus will be on some practical field issues; a few potential pitfalls and tips based on personal anecdotal experience will also be noted.

It should be noted that References 2 and 3 standards provide excellent detailed discussions on a variety of practical issues related to pump testing that will not be repeated in these columns.

Pump Head

The pump head accounts for the difference in the sums of three elements of energy per unit mass between the pump suction and discharge: pressure, elevation, and velocity. References 2 and 3 as well as many textbooks provide detailed discussions on the individual terms. Some practical aspects of the pressure element of head are treated below. The elevation and velocity elements will be discussed in a subsequent column.

Pressure

In most industrial systems, the pressure component is the dominant head term (the others can't be ignored, however, especially in low head pump applications). Threaded test connections are fairly common in the field, particularly in the pump discharge line—a point where you're also most likely to find a permanently installed gauge.

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Unfortunately, sometimes there are other devices between the pump and the gauge, such as a discharge check or control valve. But all isn't lost if this is the case—the head loss across the valve can be estimated from manufacturer (preferred) or generic performance curves once flow rate is known (or estimated). It is also important to note that the pressure *downstream* of a throttled discharge valve is actually a better indication of what the system *needs* than is the pressure at the pump discharge. If pressure can be measured upstream and downstream of the valve, an immediate indication of potential energy savings from eliminating throttling losses can be established from the following expressions of fluid power:

$$P_{fl}\,(\text{hp}) = \frac{\text{gpm} \cdot \text{head loss (ft)} \cdot \text{s.g.}}{3690}$$

or

$$P_{fl}\,(\text{kW}) = \frac{\text{m}^3\text{/hr} \cdot \text{head loss (m)} \cdot \text{s.g.}}{367}$$

where s.g. is specific gravity.

The actual electrical power associated with the throttling loss is typically 1.3 to 2 times this value because of inefficiencies in the motor and pump.

Test pressure gauges, rather than permanently installed gauges, should be used if at all possible. It has been my observation that a large fraction of permanently installed gauges, particularly in the absence of a good calibration program, are unreliable. On many occasions, I've found gauges whose pressure indications don't change when removed from the process—even when the needle exhibited some "wiggle" (suggesting the gauge was responding to pressure fluctuations in the system) when connected. The gauge shown in Figure 1 is such an example.

Fortunately, there is usually an instrument isolation valve where permanently installed gauges are located, which makes for a more pleasant permanent gauge removal and test gauge installation experience (a little dry humor there). These valves not only simplify test gauge installation—they can also be throttled to dampen pressure fluctuations that often exist in pumping systems, making the job of gauge reading a little easier. But care is needed when doing this—the valves are often nearly completely closed to achieve the desired damping, and it is very easy to go to the fully isolated condition. Should the valve completely isolate the gauge from the process, the gauge will continue to read the pressure that existed at valve closure (unless there's leakage around the gauge threads or the valve seat), which may or may not represent actual system conditions. A good way to use the valves for damping is to start with them fully closed (such as when you're installing the test gauge) and with pressure relieved from the stub between the valve and the test gauge. Then gradually crack the valve open and stop when you first see a change in the indicated pressure. A small needle valve inserted between the gauge and the test connection is much easier to use in this way than the gate or ball valves often used as isolation devices in the field.

Hydraulic snubbers are also used sometimes to reduce flutter in gauge indication (as well as to protect the gauge from pressure spikes, such as water hammer). If used, a test snubber known to be in good shape is recommended instead of a possibly degraded (plugged) permanent one.

My personal preference for pressure readings is a small test transducer (such as shown in Figure 2), which provides an electrical output, such as 1 millivolt per psig. The average transducer signal can be monitored on a multimeter with minimum/maximum/averaging capability, eliminating the need for a valve or hydraulic snubber pressure damping and/or "eyeball averaging". By collecting pressures in this way, the range of pressure fluctuations can also be noted (using the minimum and maximum values). Significant pressure fluctuations may indicate unstable pump and/or system operation, information worth noting on its own merits.

Comments/questions welcome by e-mail: a85@ornl.gov.

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[1] Although tailored to pumping systems, much of what is discussed can either be applied directly or in analogous fashion in other centrifugal load systems.

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1) United States Industrial Electric Motor Systems Market Opportunities Assessment, U.S. DOE, December 1998.
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3) ANSI/HI 1.6-1994, Centrifugal Pump Tests.
4) ANSI/IEEE Std. 120-1989, IEEE Master Test Guide for Electrical Measurements in Power Circuits.
5) IEEE Std. 112-1991, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

Figure 1. Test pressure gauge.

Figure 2. Test transducer.

Root Cause Failure Analysis On AC Induction Motors

By John M. Machelor, Motor/Drives Systems Specialist, Motor Challenge Program, MACRO International Inc.

This is the fourth in a series of articles by Mr. Machelor. In the January 1999 issue, John concluded his discussion of the most common electrical failure modes of induction motors and how to identify their root causes. The present article shifts the focus to mechanical motor failures. The next article will continue our investigation of AC induction motor bearing failures.

Mechanical-related failures of induction motors have a most common (70% to 80% of all failures) mode, which is bearing failures. These have many direct causes, all of which can again be traced to a root cause. The important thing to note is that the vast majority of all bearing failures are easily preventable.

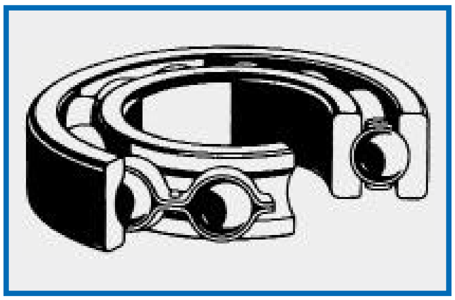

Figure 1. Typical anti-friction ball bearing.

We will focus our attention on anti-friction bearings, the most common type found in NEMA AC induction motors. Specifications for the design of anti-friction bearings are covered by the Anti-Friction Bearing Manufacturers Association, Inc. (AFBMA). Anti-friction bearings are called rolling element because they all consist of an inner and an outer ring (race) encircling some type and number of rolling element. The elements are either balls or various shaped rollers. Figure 1 depicts a typical anti-friction ball bearing. As we discuss the damage to and modes of failure of anti-friction bearings, one critical characteristic of them will stand out—except for the lubricating film set up by the grease or oil in the bearing, the inner and outer races can (and often do) come into metal-to-metal contact with the rolling elements!

Bearing damage leading to ultimate failure can occur when a motor bearing is motionless or rotating. Let's examine one of the most common types of damage incurred by non-rotating bearings.

False Brinelling: (See Figure 2.) This condition can occur whenever a non-rotating bearing is subjected to external vibration. (Note: There is another type of brinelling called true brinelling that occurs in rotating bearings. Damage to rotating bearings will be discussed in a future article.) When the bearing isn't turning, a protective oil film cannot form between the races and the rotating elements. Thus, there can be metal-to-metal contact between the races and rotating elements, and the small, relative motion between these parts causes wear marks on both races at the location of each rotating element. False brinelling can occur during transportation (typically truck or rail) and during motor storage if the storage area is subject to vibration. False brinelling occurs frequently with the bearings of motors installed on "spare" or "backup" systems in the plant. A typical example of this is parallel motor/pumps where one system is considered to be the primary system and the other system only a backup. The primary system may run for weeks, months, or even longer before the backup system is ever energized. The problem is that even though the backup is not running, it is actually "piped" into the system. Vibrations associated with the running system are being constantly transmitted to the backup system. Thus, severe false brinelling can occur on both the backup motor and pump bearings.

Several years ago, I encountered this "parallel pump" situation at a chemical plant where I was doing a system survey. This facility had literally several hundred primary/backup pump arrangements and their maintenance team admitted that they could not remember the last time some of the backup systems had been used. With this history in mind, I suggested a random

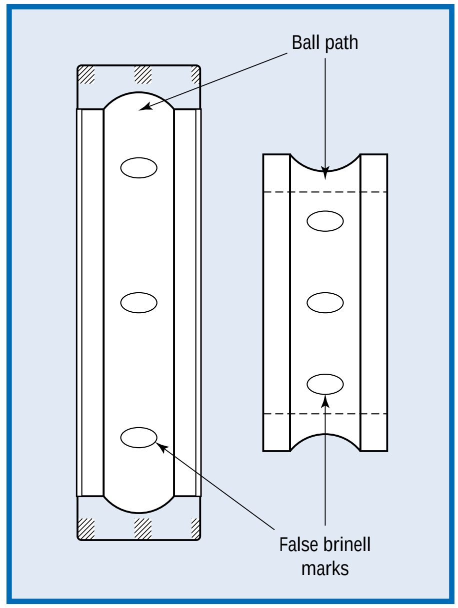

Figure 2. False brinelling.

energizing of ten backup systems which maintenance assured me were "ready to go". Unfortunately, they were right. Of the ten backup systems we energized, seven failed within a day, two failed within a week, and the remaining one managed to last 3 weeks. In all ten cases, a bearing on either the motor or the pump seized up (froze). Disassembly of all ten motors and pumps revealed that all the bearings had severe false brinelling (in addition to corrosion, rust, and loss of lubricant, all to be discussed later). The maintenance team was not expecting failures at this rate, and admitted that on occasions when the primary system failed, the backup system never seemed to last very long.

Tips to Avoiding False Brinnelling

The root cause of false brinnelling is lack of knowledge that it is a problem as well as lack of a routine maintenance program. Root solutions thus involve becoming knowledgeable on the subject as well as establishing a routine maintenance program for your motors and driven equipment. To this end, here are some "tips" on avoiding this bearing failure cause:

- During transportation of motors (or any type of rotating equipment which utilizes anti-friction bearings), make sure

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False Brinelling

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the shaft is "blocked" to prevent axial or radial movement. Blocking eliminates the clearance between the races and the rotating elements in the bearing and thus prevents these parts from "banging" against one another and causing wear.

- Choose storage locations as far away as possible from sources of external vibration. For example, locating a rotating equipment warehouse adjacent to a ball mill is not a good idea. In addition, turn the shaft of all stored rotating equipment at least once a month. Turning the shaft moves the rolling elements of the bearing to a new position with each turn, and also redistributes the settled lubrication grease/oil throughout the bearing.
- In any rotating equipment plant system that has a backup or spare system, there is no reason to designate one system as the "primary" and the other as the "backup". Each system should "share the load" equally. Thus, establish a schedule to run each system roughly half the time, switching at least once a week.

Readers are welcome to send questions, comments, or suggestions to John Machelor at:
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Letters to the Editor

Energy Matters welcomes comments from readers. Letters should be typewritten and must include the author's full name, address, association, and phone number. Letters should be limited to 200 words. Address your letter to:

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We publish letters of interest to our readers on related technical topics, comments, or criticisms/corrections of a technical nature. Preference is given to letters relating to articles that appeared in the previous two issues. Letters may be edited for clarity, length and style.

Motor Repair Efficiency Loss

Recently an article in *Energy Matters* (The Northeast Premium Efficiency Motor Initiative, January 1999) mentioned that rewinding a motor results in a 2% efficiency loss. This assumption of efficiency loss is frequently reported in major rewind studies and reflected in default software calculations.

In fact, an efficiency loss after rewind may occur—but not when repairs are performed correctly. At Advanced Energy, the first motor test lab in the nation to receive accreditation by the National Voluntary Laboratory Accreditation Program (NVLAP) for motor efficiency testing of 1-150 hp motors, we have conducted over 700 IEEE 112 Method B motor efficiency tests and provided testing services to nine motor manufacturers with a notable precision of repeatability at ±0.2%.

Our findings? Certain shops are capable of maintaining or even improving motor efficiency during repair. A motor repair facility with a recognized quality program in place can provide repairs with no loss of efficiency after rewind. The current recognized motor repair quality programs include ISO-9002, EASA-Q and Proven Excellence Verification (PEV).

The savings realized if post-repair efficiency loss is eliminated have been documented. According to the Department of Energy, improved rewind practices have potential energy savings of 4,778 GWh/year—equal to $230 million—to all American industrial manufacturing facilities. A well-repaired motor also reduces costly downtime and eliminates unscheduled interruptions to production lines, which further reduce operating costs.

Please call me at (919) 857-9013 with questions, or e-mail me at jfarlow@advancedenergy.org.

Jeff Farlow, Motor Test Engineer
Advanced Energy, Raleigh, NC

How have you applied information from this newsletter on the job? Send us an e-mail: www.motor.doe.gov.

Data Logging

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The Action Plan

Once you compile the necessary information, you can draw some conclusions about your system's performance and develop an action plan to improve its overall operation. Consider these items:

- Use the data to determine your system's peak and average air demands. If you identify a pattern of fluctuating pressure at points of use or wide pressure variations during a production cycle, consider using controlled compressed air storage using intermediate flow control and receivers.
- The pressure gradient documents the air distribution system's performance. Define techniques to reduce sustained gradient to the accepted level of 1.5-2.0 psid across the air distribution system.
- Compressor discharge pressure and load profile data provide information about part-load performance. Additional storage can be engineered to improve the load/unload cycle. You might also network compressors using a compressor sequencer to direct part-load performance.
- Data from dynamic use points reveals information about piping and connections. Develop a schedule for upgrades and repairs on piping and point-of-use tools throughout the system. Use these results to develop standards and establish "Best Practices" for system management.
- The power consumption profile clearly defines your company's financial investment in compressed air generation. Evaluate the cost effectiveness of remedial actions based upon this investment.
- Use all data collected, summarize findings, and conduct a cost/benefit analysis of your recommendations. Data measurement and testing can be repeated for future evaluation of the compressed air system.

To find out about your system's performance, go out on the floor where air is consumed, and measure what is happening.

More information is available in Compressed Air Management *by Tom Taranto. Contact Bob Wilson at (800) 336-2285 for information about the book or other questions related to this article.*

See Coming Events on page 10 for upcoming workshops on the Fundametals of Compressed Air Systems.

Coming Events

Understanding Pump Systems/PSAT Workshops

The following sessions present the fundamentals of optimizing industrial and municipal pump systems. The workshops will present case studies and will focus on Pump System Assessment Tool (PSAT).

- June 6 in Milwaukee, WI
- June 20 in Chicago, IL
- August 29 in San Diego, CA

Call Anna Maksimova at (360) 754-1097, ext.100 for more information.

Adjustable Speed Drive Application Workshops

These workshops address the fundamentals of ASDs and demonstrate the ASDMaster software.

- June 1-2 in Reading, PA
- June 10 in Springdale, AK

Call Anna Maksimova at (360) 754-1097, ext.100 for more information.

MotorMaster+ Software Demonstration

This demonstration of MotorMaster+ software will be at the American Water Work's Association's Annual Conference.

- June 20-24 in Chicago, IL

Call Anna Maksimova at (360) 754-1097, ext.100 for more information.

Fundamentals of Compressed Air Systems

These 1-day Compressed Air Systems training seminars are targeted to plant engineers and maintenance personnel who are responsible for ensuring optimum performance of compressed air systems.

- May 12 in Allentown, PA
- May 13 in Knoxville, TN
- May 21 in Baltimore, MD
- May 26 in Salt Lake City, UT
- May 28 in Dallas, TX
- May 28 in Nashville, TN
- June 3 in Detroit, MI
- June 4 in Atlanta, GA
- June 4 in Philadelphia, PA
- June 8 in Pittsburgh, PA
- June 11 in San Diego, CA
- June 11 in Greenville, SC
- June 11 in Richmond, VA
- June 14 in San Antonio, TX
- June 15 in Kansas City, KS
- June 17 in Phoenix, AZ
- June 22 in Oklahoma City, OK
- June 22 in Tampa, FL

For information or a registration form, call (800) 862-2086.

Energy Efficiency Forum for Water/Wastewater Facilities

The goal of this forum is to help managers and operations personnel of municipal and industrial systems find workable energy management solutions.

- August 29-31 in San Diego, CA

Call Laura Boland at (918) 831-9179 for more information.

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Information Clearinghouse

Do you have questions about using energy-efficient electric motor systems? Call the OIT Challenge Programs Information Clearinghouse for answers, Monday through Friday 9:00 a.m. to 8:00 p.m. (EST).

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